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Printed Red-Green-Blue liquid crystal lasers

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Abstract: We present printable laser devices formed by dispersing dye-doped chiral nematic liquid crystals in solution-processible polymers. Unlike current technology, this allows lasers to be formed on a wide variety of surfaces, e.g. paper, plastic, metal.
OCIS codes: (230.3720) Liquid crystal devices; (160.5293) Photonic bandgap materials.

1. Introduction

There has been considerable recent work investigating photonic band-edge lasing in dye-doped chiral-nematic liquid crystals [1,2]. Compared to other forms of organic and inorganic band-edge and distributed feedback (DFB) lasers, liquid crystal (LC) band-edge lasers have the significant advantage of self-organization into regular helical structures, generating a periodic refractive index and a photonic band-gap ideally suited to lasing. Such systems have been shown to offer switchable, tunable and low-threshold band-edge laser emissions across a wide proportion of the spectrum from the ultraviolet through to the near infra-red. In this paper, we further enhance the applicability of such lasers by dispersing them in a solution-processible polymer and subsequently printing the lasers on a variety of substrates that would be incompatible with conventional laser technology, including glass, plastic, metal and paper, for example.

2. Experimental

The sample laser films, consisting of dye-doped chiral liquid crystal dispersed in polymeric binder were prepared in the following manner. Chiral nematic liquid crystals were created by adding BDH1281 (Merck GMbH) to the nematic liquid crystals BL006 or BL093. For the red, green and blue laser films the dyes (DCM, Coumarin 540A and Coumarin 504; supplied from Exciton) were used at 1% w/w. Mixtures were examined in aligned 10 μm glass cells to measure the absorbance and fluorescence characteristics.

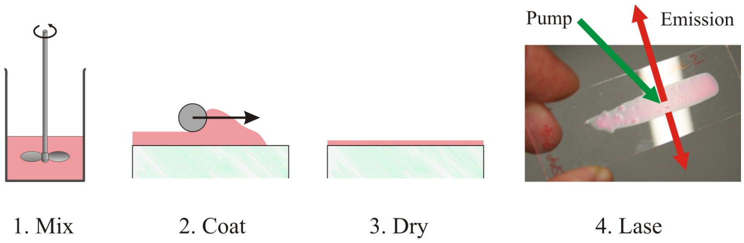

Figure 1. Experimental schematic of the printable laser preparation, deposition and emission process.

To form the emulsions, the dye-doped chiral nematic lasing materials were added at a concentration of 5% w/w to poly-vinyl alcohol (PVA) solution (Sigma-Aldrich Ltd, molecular weight 10,000 amu, 20 % w/w in deionized (DI) water) and emulsified at 100 rpm for 10 minutes using an overhead stirrer (Eurostar, IKA). Films were coated using a bar coater. The wet thicknesses of films described here were all 80 μm. A schematic of the experimental process is presented in Figure 1. The lasing characteristics were examined through optical pumping by a Nd:YAG laser (Polaris II, New Wave Research) with 4 ns pulse duration and repetition rate of 1 Hz. For the red-green-blue laser samples, an optical parametric oscillator, pumped by the third harmonic of an Nd:YAG laser (Spitlight, Innolas), was used to excite the samples at the shorter wavelength of 430 nm.

3. Results and summary

When optically pumped, the LC emulsions gave rise to circularly polarized laser emissions, Fig. 2, at wavelengths that matched the locations of the long band-edges observed in the pre-emulsified mixtures indicating that the emulsification process and coating has only a negligible impact on the lasing behavior. Fig. 2 depicts the blue, green, and red output profiles from the laser emulsions that were recorded approximately 30cm away from the sample. The emission wavelengths are found to occur at 480 nm, 528 nm, and 599 nm for the blue, green, and red samples respectively. There was little change in the linewidth of the samples relative to non-emulsified equivalents studied previously, [3] which is strong evidence that the quality factor of the periodic structure is unchanged when the chiral nematic is confined in the droplets. Overall, these results demonstrate that it is possible to encapsulate the liquid crystalline samples in a polymer binder and still retain the essential features of the dye-doped chiral nematic band-edge laser.

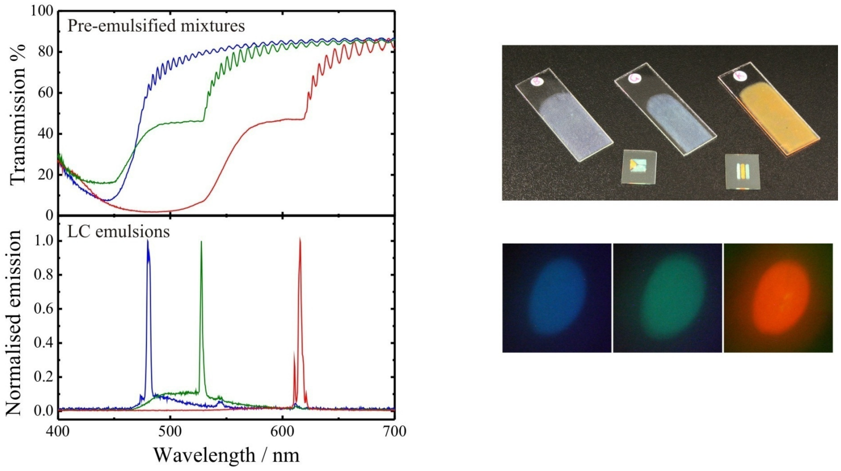

Figure 2. Transmission vs. wavelength for the RGB laser films; pre-emulsified mixtures in aligned cells (left, top); laser emission after optical pumping (left, bottom); coated films on microscope slides (right, top); photographs of the emission in the far-field.

The paintable laser samples are not only restricted to glass substrates. The coatings can be readily formed on alternative substrates including flexible polyethylene terephthalate (PET), aluminium and paper, which would otherwise be incompatible with conventional LC device fabrication procedures that require alignment layers and a uniform device thickness. The coatings can be uniformly deposited over large areas, with lasing occurring anywhere over the coated area, and can be easily scaled to a roll-to-roll manufacturing process.

A further benefit of the printable laser approach is to make active laser films of increasing complexity, and with unique optical signatures, for security, identification-friend-or-foe (IFF) applications, amongst others. Figure 3 shows the results for a stack of RGB printed laser films with resultant “white light” emission in the in the far field composed of individual RGB laser wavelengths.

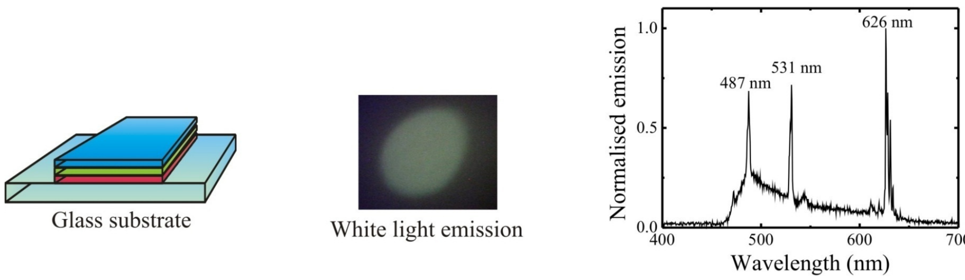

Figure 3. Sequential RGB stack (left); shown are photograph of laser emission in the far field (middle) and laser spectra for the stack (right).

5. References

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